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GEOTECHNICAL DESIGN MANUAL

CHAPTER 16

LANDSLIDE ANALYSIS AND MITIGATION

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CHAPTER 16

Landslide Analysis and Mitigation

16.1 OVERVIEW

This chapter addresses the assessment of landslides in soil and rock, and the development of the mitigating measures needed to stabilize the landslide.

16.2 DEVELOPMENT OF DESIGN PARAMETERS AND OTHER INPUT DATA FOR LANDSLIDE ANALYSIS

In addition to the site reconnaissance and geotechnical investigation requirements described in NYSDOT GDM Chapter 2, the exploration requirements provided in Special TRB Report 247 “Landslides Investigation and Mitigation”, Turner and Schuster, editors (1996) or “Landslides in Practice” by Cornforth (2005).

16.2.1 Use of Aerial Photographs

Landslides are recognizable in aerial photographs by the following slide-formed features or conditions:

- hillside scars;
- disturbed or disrupted soil and vegetation patterns;
- distinctive changes in slope or drainage pattern;
- irregular, hummocky surfaces;
- small undrained depressions;
- steplike terraces;
- steep hillside scarps.

Aerial photographs are also valuable aids for recognizing landslide-susceptible terrain (see Table 16-1). Typical locations that have a potential for landslides include:

- steep hillsides characterized by clayey soils, fractured bedrock, tilted strata, seeps on springs, gully erosion or deforested slopes;
- cliffs and banks undercut by streams and waves;
- crescent-shaped or linear cracks in the surface soils;
- tilted utility poles and trees;
- old landslides, which may indicate previous instability.

Landform	Mass Wasting and landslide Susceptibility
Till (Ground Moraine)	Tills along steep slopes have a tendency to slip along the bedrock plane if moisture and slope gradients are sufficient to create little shear resistance. Soil creep occurs along all hillsides and moves particles slowly downslope.
Morraines	Are moderately susceptible to landslides. Fine-textured soils and steep, rugged, massive formations have the highest hazards. Past debris flows, slides, and slumps may

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	be observed from aerial photographs. Steep embankments created by stream undercutting or excavation may be highly unstable.
Drumlins	Are not typically highly susceptible to sliding. Materials are moved downslope by a combination of creep, front heave and erosion.
Eskers	Are stable because of their granular composition and excellent drainage. Surface soils that develop are moved downslope by creep, frost action and erosion.
Kames	Are relatively stable, owing to their granular composition and excellent internal drainage. Surface soils that develop are moved downslope by soil creep, frost action and/or erosion.
Outwash	Are relatively stable. If the outwash materials are underlain by more impervious deposits, such as till, unstable conditions will occur along cuts where the till is exposed and where lateral support of the outwash is removed.
Lake Beds	Landslides do not normally occur in lake bed formations under their natural, flat topographic conditions. However, if the lake bed is either dissected, exposed, or eroded by a lake or stream; or vertically cut in excavations; unstable conditions may result.
Sand Dunes	Are very stable since they are uniform in composition and well drained.
Flood Plains	Minor slumping is common along stream banks where undercutting has oversteepened slopes, especially along the outer edges of meanders in meander flood plains. Slumping hazards along stream banks are increased after floods. Terraces of marine or lacustrine materials may contain varved materials and fine soil textures and therefore be extremely susceptible to sliding upon small increases in their moisture content.
Alluvial Fans and Valley Fans	Alluvial fans and valley fills, which are found in flat, lowland positions, are generally stable with respect to landslides and the processes of mass wasting. Where stream dissection has oversteepened slopes in dissected regions of continental alluvium, potential slide zones develop.
Beach Ridges	The uniform composition and low topographic relief of these landforms do not present conditions susceptible to mass wasting or sliding.

Table 16-1 Landslide Susceptibility of Various Landforms

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16.2.2 Preventive and Remedial Works

- Drainage (most important)
 - Horizontal drains
 - Drainage trenches or galleries
 - Control of water into the slide area (surface)
- Piles
 - Not applicable to deep-seated movements
 - Pile driving (vibrations) could create more instability
- Retaining Structures
 - Unless the slide is very small (extent), do not consider. Walls designed to resist the total load of a slide (deep-seated) would be very expensive. Add to this the uncertainty involved in making this determination, the use of walls as a treatment should be approached with caution.

16.3 LANDSLIDE TERMINOLOGY

16.3.1 Landslide Dimensions

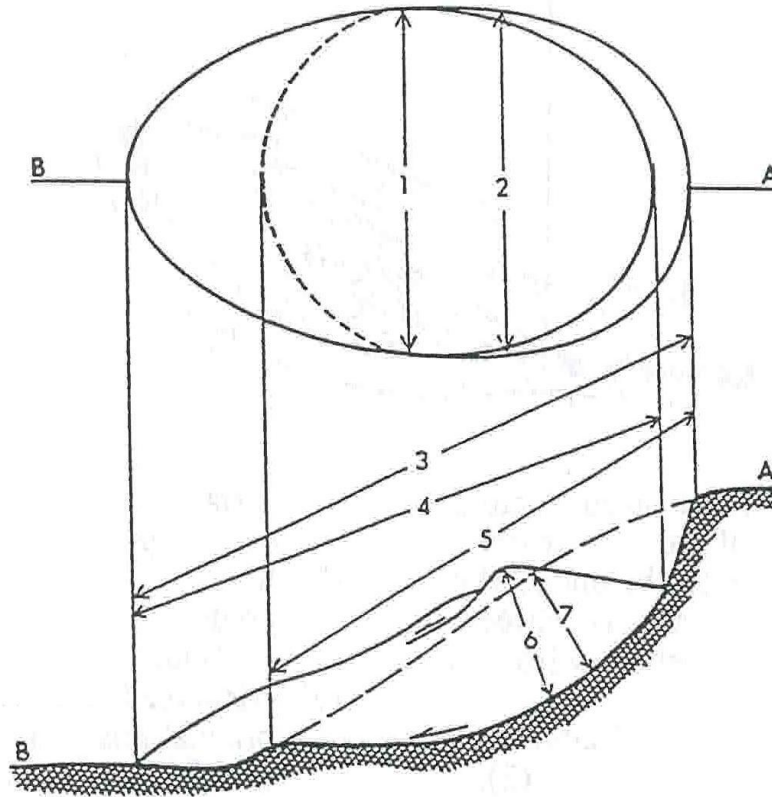


Figure 16-1 Landslide Dimensions
(IAEG Commission on Landslides and Other Mass Movements)

1. Width of the displaced mass, W_d , the maximum breadth of the displaced mass perpendicular to the length, L_d .
2. Width of the rupture surface, W_r , the maximum width between the flanks of the landslide, perpendicular to the length, L_r .
3. Total length, L , the minimum distance from the tip of the landslide to its crown.
4. Length of the displaced mass, L_d , the minimum distance from the tip to the top.
5. Length of the rupture surface, L_r , the minimum distance from the toe of the surface of rupture to the crown.
6. Depth of the displaced mass, D_d , the maximum depth of the displaced mass, measured perpendicular to the plane containing W_d and L_d .
7. Depth of the rupture surface, D_r , the maximum depth of the rupture surface below the original ground surface measured perpendicular to the plane containing W_r and L_r .

16.3.2 Landslide Features

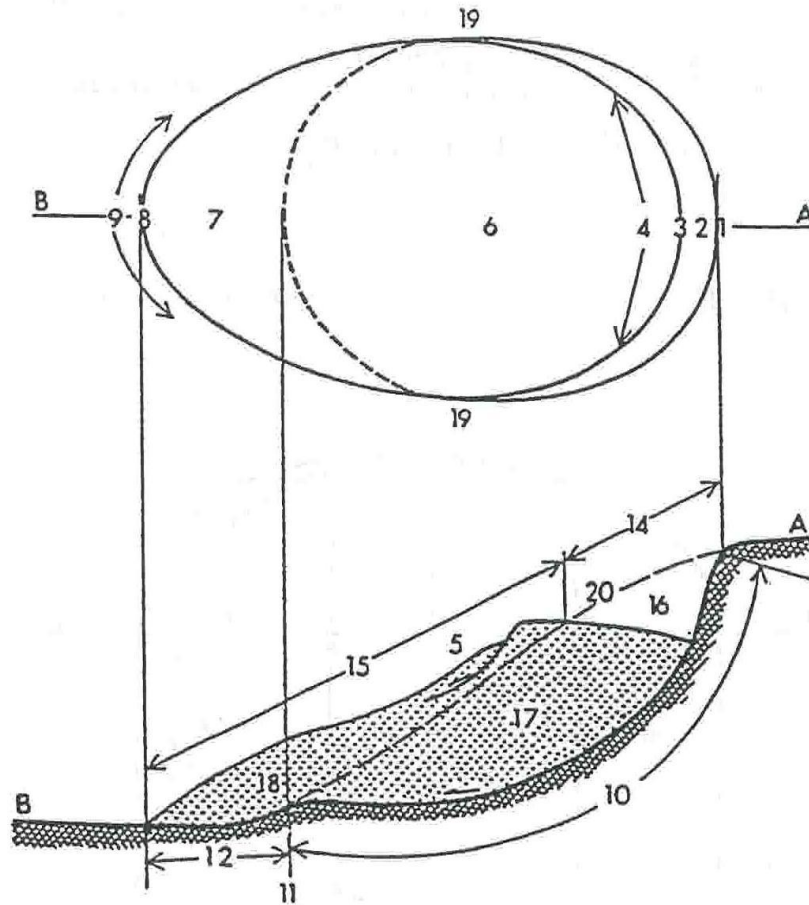


Figure 16-2 Landslide Features
(IAEG Commission on Landslides and Other Mass Movements)

8. **Crown:** The practically undisplaced material adjacent to the highest parts of the main scarp.
9. **Main Scarp:** A steep surface on the undisturbed ground at the upper edge of the landslide caused by movement of the displaced material away from the undisturbed ground.
10. **Top:** The highest point of contact between the displaced material (13) and the main scarp (2).
11. **Head:** The upper parts of the landslide along the contact between the displaced material and the main scarp (2).
12. **Minor scarp:** A steep surface on the displaced material of the landslide produced by differential movements within the displaced material.
13. **Main body:** The part of the displaced material of the landslide that overlies the surface of rupture between the main scarp (2) and the toe of the surface rupture (11).
14. **Foot:** The portion of the landslide that has moved beyond the toe of the surface rupture (11) and overlies the original ground surface (20).
15. **Tip:** The point on the toe (9) farthest from the top (3) of the landslide.

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16. **Toe:** The lower, usually curved margin of the displaced material of a landslide, it is the most distant from the main scarp (2).
17. **Surface of rupture:** The surface forming the lower boundary of the displaced material below the original ground surface.
18. **Toe of surface of rupture:** The intersection (usually buried) between the lower part of the surface of rupture (10) of a landslide and the original ground surface.
19. **Surface of separation:** The part of the original ground surface now overlain by the foot (7) of the landslide.
20. **Displaced material:** Material displaced from its original position on the slope by movement in the landslide. It forms both the depleted mass (17) and the accumulation (18). It is shown dotted in the figure.
21. **Zone of depletion:** The area of the landslide within which the displaced material (13) lies below the original ground surface (20).
22. **Zone of accumulation:** The area of the landslide within which the displaced material lies above the original ground surface (20).
23. **Depletion:** The volume bounded by the main scarp (2), the depleted mass (17) and the original ground surface (20).
24. **Depleted mass:** The volume of the displaced material which overlies the rupture surface (10) but underlies the original ground surface (20).
25. **Accumulation:** The volume of the displaced material (13) which lies above the original ground surface (20).
26. **Flank:** The undisplaced material adjacent to the sides of the rupture surface. Compass directions are preferable in describing the flanks but if left and right are used, they refer to the flanks as viewed from the crown.
27. **Original ground surface:** The surface of the slope

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16.4 LANDSLIDE SUSCEPTIBILITY

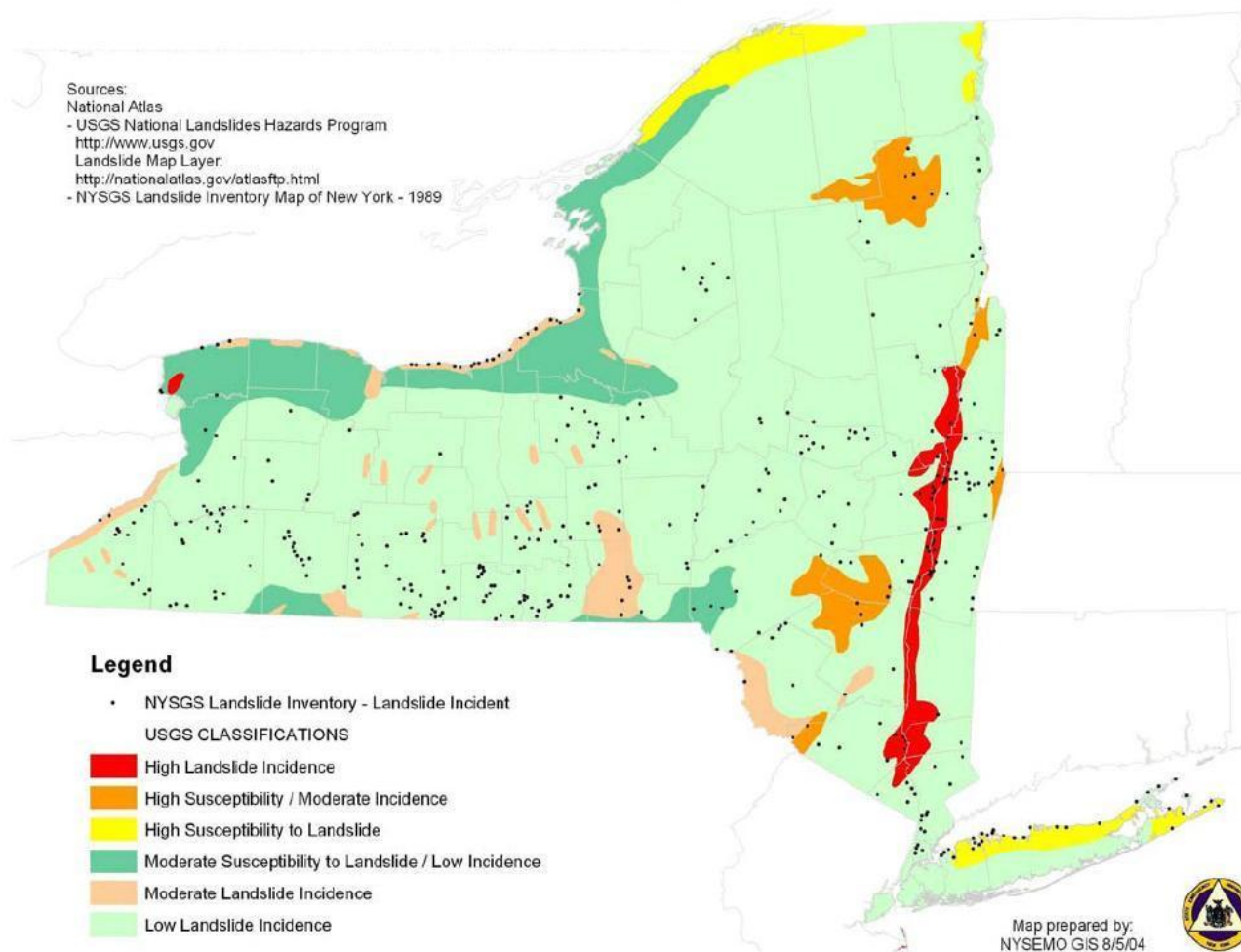


Figure 16-3 Comparison of New York State Geological Survey Landslide Inventory with USGS National Landslide Overview Map of the Continental US (NYS Hazard Mitigation Plan, Division of Homeland Security and Emergency Services)

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16.5 DESIGN REQUIREMENTS

For landslides in soil and soft rock, the slope stability analysis methods and design requirements specified in NYSDOT GDM Chapter 10 shall be used. For rockslides, the stability analysis method specified in NYSDOT GDM Chapter 15 shall be used. The detailed requirements for analysis and mitigation design of landslides shall in addition be conducted in accordance with Special TRB Report 247 “Landslides Investigation and Mitigation”, Turner and Schuster, editors (1996) or “Landslides in Practice” by Cornforth (2005).

16.6 REFERENCES

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